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Performance analysis of Medical Image Compression using DCT and FFT Transforms

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ABSTRACT

There is a high demand for image compression since it reduces the computational time, which in turn reduces the storage and transmission costs. Image compression involves reducing excessive and irrelevant data while maintaining reasonable image quality. Image compression techniques such as the Discrete Cosine Transform (DCT) and Fast Fourier Transform (FFT) are the focus of this study. These tools were selected because of their wide application in image processing; one example is JPEG (Joint Photographic Experts Group), which uses DCT for compression. A comparison is made between DCT and FFT, two compression methods implemented in MATLAB. CT and MRI images are used for an experiment, the quality of an image is determined by various parameters. To perform DCT the filter mask is used and a threshold is used for FFT to keep the top coefficient values. The experimental findings are compared and evaluated in terms of Peak Signal to Noise Ratio (PSNR) and Compression Ratio (CR).

Keywords: Compression, Compression ratio, DCT, FFT, PSNR.

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INTRODUCTION

Image processing advancements have played a critical role as a trigger in medical imaging in this new era. In the healthcare industry, digital medical images are required for a quick and accurate diagnosis. Medical image compression seeks to decrease the amount of data in medical images so that they can be stored and communicated effectively. Only when the compression technique used preserves all of the necessary diagnostic information as well as the image resolution can an effective diagnosis be made. When the data size is tiny, it takes a short amount of time to reconstruct the image in numerous medical imaging modalities. However, if the amount of raw data is large, processing time will increase as well. However, if the raw data is excessive, the processing time will also increase. This stimulates the probe to process data more quickly, making enormous data sets possible [1].

In the case of multimedia communication, image data has received the highest level of preference due to its widespread usage and largest share of bandwidth consumption. As a result, developing efficient image compression algorithms for effective and efficient bandwidth consumption is both vital and challenging for academics. As a result, the image data must be processed and compressed. The performance of two image compression methods, DCT and FFT, is compared in the proposed work [2].

Data compression can be defined as a method for taking an input image F and generating a shorter version of the image c(F) with fewer bits than F. Decompression, on the other hand, takes compressed data c(F) and creates or reconstructs the data F', as shown in Figure1. The combination of compression (coding) and decompression (decoding) techniques is sometimes referred to as a "CODEC" [3].

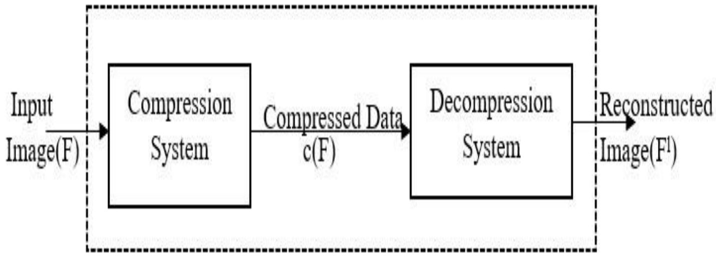

Figure.1 Block Diagram of CODEC.

Medical images are one of the most significant bits of info concerning patients, and they are digital representations of human body images. These images let doctors to see inside the body for a more accurate diagnosis. It also aids keyhole procedures, which allow doctors to reach internal organs without creating large incisions in the body. Images such as X-rays, CT scans, MRI scans, and ultrasound scans include a vast amount of data that requires a large channel or storage capacity. Despite significant advances in storage capacity and connectivity, storage capacity is limited by implementation costs. The cost of implementation rises in tandem with storage capacity and bandwidth, affecting the cost of medical imaging. Quick access to patient data, especially in the case of telemedicine, saves time, money, and the patient's life. Fast data processing is critical in such applications, which includes both reconstruction and compression of medical images [1].

Image Compression Techniques

There are two compression techniques: one is lossy compression and the other is lossless compression.

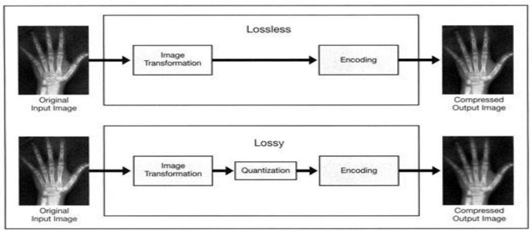

Figure2. Lossless and lossy image compression process.

A. Lossy Image Compression:

When attempting to reconstruct information from compressed data, one may obtain something that is similar to, but not identical to, the original. In lossy compression techniques, compression is employed to enhance throughput however at a loss of quality.

B. Lossless Image Compression:
The reconstructed image is that the same as the original image however the compression quantitative relation is a smaller amount. This method can be used in cases where no data loss is expected, for example in the medical field, where image data is rarely lost since a bit of medical information is also necessary for a diagnosis [4].

Image Compression Methods

The following image compression algorithms are highlighted in this study:

1 Discrete Cosine Transform (DCT).
2 Fast Fourier Transform (FFT).
3 These techniques were chosen since many of them are widely used in image processing. The JPEG is an example of a compression technology that uses DCT and FFT.

Discrete Cosine Transform:

The DCT uses cosine functions to transform a signal from spatial to frequency representation. Each element in the original block of an 8-bit image is in the range [0,255]. The adjusted range is [0,255] to [-128,127] after subtracting the range's midpoint (the number 128) from each element in the original block. The DCT separates images into frequency range parts. The quantization stage eliminates less important frequencies, whereas the decompression stage recovers the image utilising the important frequencies [5].

Forward 2D_DCT transformation:

$$F(u,v) = \frac{2}{N} C(u)C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (1)$$

for u=0……, N-1 and v=0,………,N-1 where N=8 and

$$C(k) = \begin{cases} \frac{1}{\sqrt{2}} & for\ k = 0 \\ 1 & otherwise \end{cases}$$

Inverse 2D_DCT transformation:

$$f(x,y) = \frac{2}{N} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} C(u)C(v)F(u,v) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \cos\left[\frac{\pi(2y+1)v}{2N}\right] \quad (2)$$

for x=0,………..,N-1 and y=0,…………,N-1 where N=8

DCT has a number of advantages [6]:

a. It has the ability to cram as much information as possible into the smallest number of coefficients.
b. It reduces the appearance of a block, known as blocking artefact, which occurs when the boundaries between sub-images become noticeable.

Fast Fourier Transform (FFT):

In 1805, Carl Friedrich Gauss developed the FFT algorithm. It calculates the Discrete Fourier Transform (DFT). The period field divides the largest M = NxN matrix into little size Ns of DFT. The operational and simple technique is the new-fangled Radix-2 to Decimation in Time (DIT) FFT. This is also used to compute the DFT for 2n points. The weights are multiplied by the indices in the FFT approach. The output signals must be in the bit opposite form of the input signal. The imaginary portion is referred to as the compound conjugate uniformity [7].
FFT is a filtering algorithm that provides for extremely accurate low pass and high pass filtering. FFT is also a technique for reducing the amount of time it takes to compute huge matrices [8].
FFT is a fast and efficient method of calculating DFT that decreases the number of arithmetic computations from O(N)2 to O(Nlog2N) [9]. As seen in equations 3 and 4, the FFT is a computationally efficient approach for computing the DFT and IDFT.

$$H(u,v) = \frac{1}{mn}\sum_{x=0}^{m}\sum_{y=0}^{n} h(x,y)e^{-j2\pi(\frac{ux}{m}+\frac{vy}{n})} \qquad (3)$$

$$h(x,y) = \sum_{x=0}^{m}\sum_{y=0}^{n} H(u,v)e^{j2\pi(\frac{ux}{m}+\frac{vy}{n})} \qquad (4)$$

Image Compression Performance Criteria:

Two essential metrics that can be used to quantify performance are the compression ratio (CR) and the performance monitoring of the reconstructed image using peak signal noise ratio (PSNR) [5].

Compression ratio: The compression ratio represents the ratio between the original image size and the compressed image size.

$$CR = n1/n2 \qquad (5)$$

Distortion measures: Using MSE to calculate distortion in a reconstructed image (MSE).

$$MSE = \frac{1}{mn}\sum_{0}^{m-1}\sum_{0}^{n-1}\|f(i,j) - g(i,j)\|^2 \qquad (6)$$

In the field of image compression, PSNR has become a commonly acknowledged quality assessment.

$$PSNR = 20\log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right) \qquad (7)$$

LITERATURE REVIEW

Dr. NSSR Murthy et al. [10] In this study, a comparative study of performances of FFT and DCT is carried out. Results showed that the larger the truncation window, the higher the image quality. This is because the larger the window, the more information is retained. Also, the less texture image will have superior quality (higher SNR) in the recovered image since it retains the low frequency section, whereas texture usually generates high frequency. As a result, the recovery performance of FFT is found to be slightly superior than that of DCT. It decreases the amount of data that must be stored. Encoding the decoding parameters and transferring them independently from the compressed database files can also considerably improve data security and decreases the cost of data backup and recovery in computer systems by storing backups of big database files in compressed format.

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Ms. Anshula Jain et al. [2] The author presents, the DCT and FFT compression approaches and compare their outcomes using Matlab tool, Graphical User Interface (GUI). These findings are based on two compression approaches with varying compression rates, i.e. compression rates of 10%, 40%, and 70%. The findings indicate that DCT is a superior approach over FFT. While the compression method works well with images with low levels of noise, its lossy nature makes it unable to handle medical images such as CT scans and X-rays.

Fifit Alfiah et al. [11] The research includes a study of image compression methods in order to compare the best techniques for lossy image compression. These results conclude that, Among the three methods of image compression (DCT, FFT, and DWT), there are four variations of the evaluation ratio of image compression starting from 10%, 30%, 50%, and 70%. By comparing the three approaches with four different visual assessments, it is possible to determine which approach has the best compression ratio for an image of the given size. In terms of image compression, the DCT method outperforms the DWT and FFT approaches.

METHODOLOGY

All DCT using MATLAB Blockproc () Function: In MATLAB, will be doing a block average on an image to minimize its size for processing. Block averaging is a technique for combining non-overlapping blocks of an image into a single pixel. It is easy to specify a function that should be applied to image blocks using MATLAB blkproc or blockproc (i.e., the pixels of the resultant picture are the average of the original's M x N blocks).

DCT method used for compression:

1. Read Image.
2. If RGB image convert it into Gray.
3. Divide the image into 8X8 block using blockproc method.
4. apply DCT2 on each block downshift the intensity levels by 256
5. Designed a filter (filt6, filt15, filt36) mask to remove the coefficients in zig zag manner.

Filt36=	Filt15=	Filt6=
[1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 0 0 1 1 1 1 1 0 0 0 1 1 1 1 0 0 0 0 1 1 1 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0];	[1 1 1 1 1 0 0 0 1 1 1 1 0 0 0 0 1 1 1 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];	[1 1 1 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0];

6. cut the coefficients using the filter filt and remove as many DCT coefficients as need by compression required.
7. Perform the inverseDCT2 on an image using IDCT2.
8. Find out CR, PSNR values to evaluate the original and reconstructed image.

FFT method used for compression:

1. Read Image.
2. If RGB image convert it into Gray.
3. Apply FFT2 on Gray image and perform fftshift to reorder the coefficients.
4. Sort the FFT coefficient values from larger to smallest (decreasing order).

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5. Compress the image by applying threshold values to keep the top coefficient values and zero out all other small coefficients.
6. Apply inverse FFT on an image using IFFT2.
7. Find out CR, PSNR values to evaluate the original and reconstructed image.

DATA ANALYSIS AND RESULTS

The evaluation of the image compression method using DCT and FFT where experiments are performed on medical CT and MRI images of size 512x512. Image datasets are obtained from Kaggle database. For comparative examination, Method implementations have been carried out on the MATLAB application, and various distinct parameters should be determined in relation to CT and MRI medical images; PSNR, CR, values have been measured in comparison of reconstructed and original images.

Table1: Compression size of medical image Compression by using CT and MRI images of size 512x 512 With DCT and FFT compression techniques.

Image Name	Image Size (DCT method)				Image Size (FFT method)		
	Original	Filt-6	Filt-15	Filt-36	99	50	30
CT1	18.2	10.8	14.8	17.8	18.2	18.1	18
CT2	19.8	10.7	16.1	19.6	19.8	19.7	19.5
CT3	33.6	14.3	22.3	31.6	33.6	32.3	32.3
CT4	22	13.3	18.6	21.7	22	21.9	22
CT5	44.3	16.7	29.3	42.9	44.3	43.6	42.8
MRI1	23.6	14.2	21.2	23.6	23.6	23.5	23.4
MRI2	23.9	14.5	21.4	23.8	23.9	23.7	23.6
MRI3	24.1	14.4	21.5	24.1	24.1	24	23.9
MRI4	25.1	15.3	22.7	25.1	25.1	25	24.9
MRI5	24.6	15.7	22.6	24.6	24.6	24.6	24.5

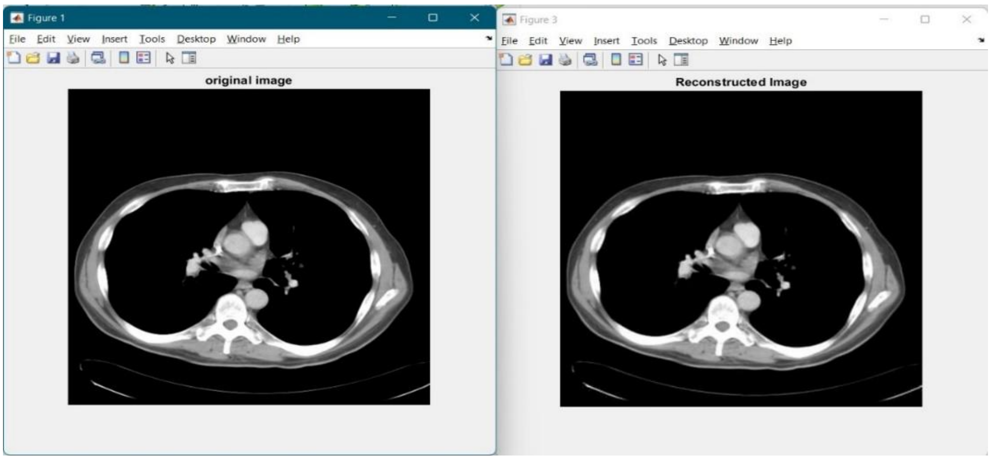

Figure 3: DCT image compression for CT image using Filt-15

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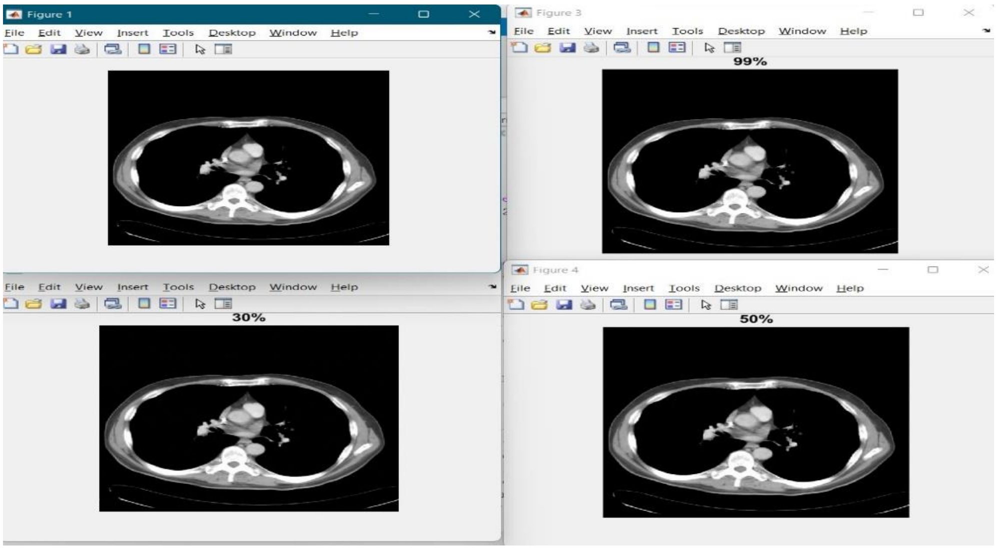

Figure 4: FFT Image compression using various threshold values.

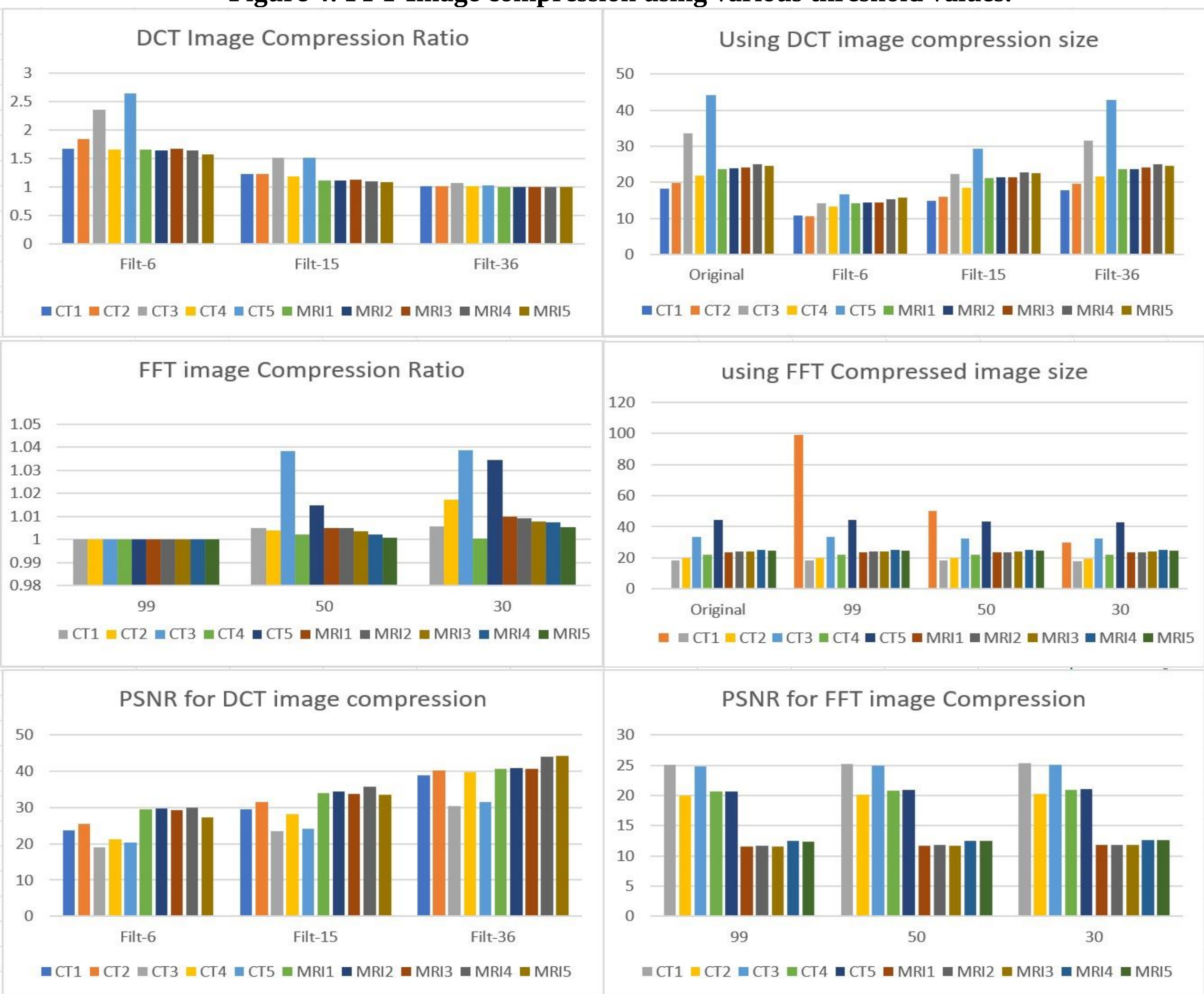

Figure 5. Graph shows CR, PSNR and compressed size of the image were evaluation values take 512x512 size of 5 CT images and 5 MRI images with DCT and FFT.

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As shown in figure 5. It is observed that the image compression using DCT method has a more successful outcome than that with FFT method. Therefore, the amount of data compression in DCT method has a greater result than that of FFT method, and the PSNR value shows a better result for DCT.

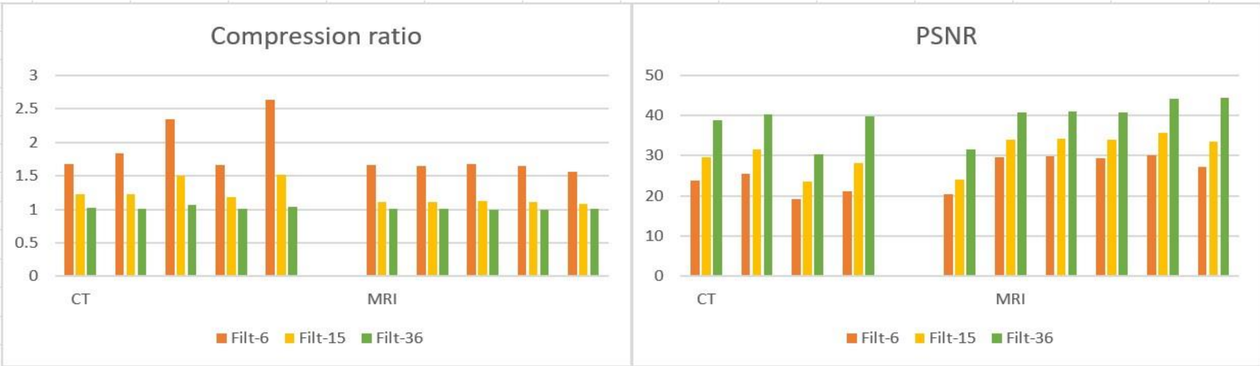

Figure 6. Graph shows CR, PSNR values for the DCT compression method.

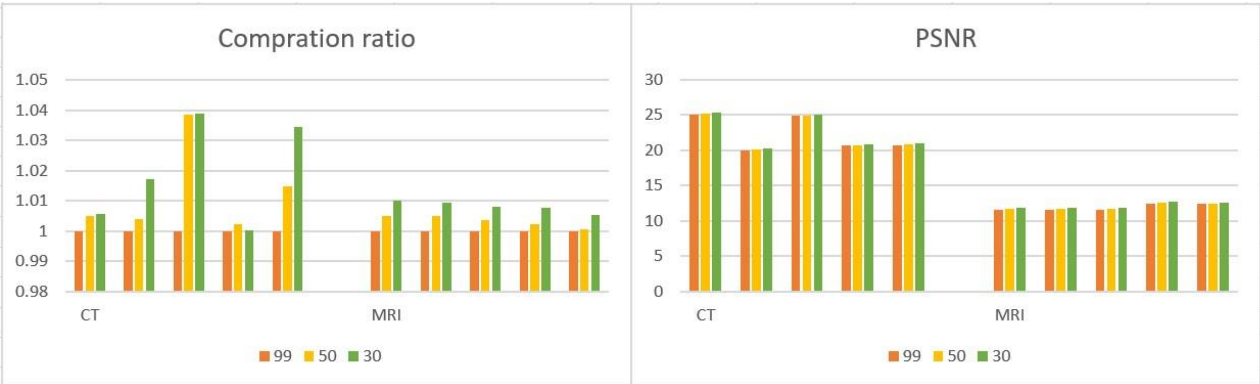

Figure 7. Graph shows CR, PSNR values for the FFT compression method

CONCLUSION AND RECOMMENDATIONS

In this study, image compression is evaluated using two transform methods: the Discrete Cosine Transform and the Fast Fourier Transform. To compress the image, different threshold parameter values were chosen to keep the 99%, 50%, and 30% top coefficient values and zero out all other small coefficients. In DCT, block averaging was performed using the blockproc MATLAB method, and a filter mask (filt6, filt15, filt36) was designed to remove the coefficients in a zig zag manner. Where, filt36 retains only 36 co-efficients out of 64, filt115 retains only 15 co-efficients out of 64 and filt16 retains only 6 co-efficients out of 64. Cut the coefficients using the filter filt and remove as many DCT coefficients as need by compression required. According to the results, DCT produces a high-quality reconstructed image and a high compression ratio.

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